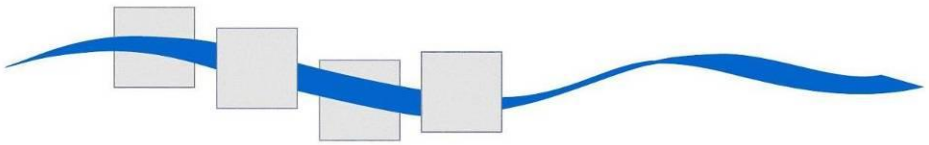

PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

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ABBREVIATIONS

APSFR	Area with Potential Significant Flood Risk
EC	European Commission
FASRB	Framework Agreement on the Sava River Basin
FB&H	Federation of Bosnia and Herzegovina
GIS	Geographic Information System
ICPDR	International Commission for the Protection of the Danube River
ISRBC	International Sava River Basin Commission
PEG FP	Permanent Expert Group for Flood Prevention
PFRA	Preliminary Flood Risk Assessment
RoS	Republic of Srpska (Republika Srpska)
UNECE	United Nations Economic Commission for Europe

1 INTRODUCTION

Floods are natural phenomena which cannot be prevented. Besides, some human activities and climate change contribute to an increase in the likelihood and adverse impacts of flood events. The assessment of flood risk is therefore a basis for decision-making in flood management at international, national, regional and local levels. The Sava River Basin countries have had a long tradition of different activities in flood management, including both structural and non-structural measures. A comprehensive elaboration of flood management in the basin has been given in the *Sava River Basin Analysis* report (ISRBC, 2009)[1]. The report provides basic information on flood prone areas, a detailed description of flood defence system including design criteria and current level of protection, overview of flood forecasting capabilities, commanding responsibilities in the countries and it provides an insight in the common actions coordinated by the Sava Commission. Common goals of the *Framework Agreement on the Sava River Basin* (FASRB)[2] contracting Parties[3] in flood management are elaborated in more details in the *Protocol on Flood Protection to the FASRB*[4]. The Protocol defines framework for cooperation and implementation of the activities aimed at creating the conditions for sustainable flood protection in the Sava River Basin.

The Protocol emphasises the importance of coordinated measures, works and activities for the reduction of flood risks throughout a river basin, and operation in accordance with "no harm rule" principle. Therefore, in order to contribute to reduction of adverse consequences of floods, especially for human health and life, the environment, cultural heritage, economic activity and infrastructure associated with floods, it was agreed that countries in the Sava River Basin will cooperate on the following tasks:

- Preparation of the *Program for development of the Flood Risk Management Plan in the Sava River Basin;*
- Undertaking of Preliminary Flood Risk Assessment;
- Preparation of flood maps;
- Development of Flood Risk Management Plan in the Sava River Basin;
- Establishment of the Flood forecasting, warning and alarm system in the Sava River Basin;
- Exchange of information significant for sustainable flood protection;
- Implementation of all measures and activities of mutual interest, originating from the abovementioned planning documents or activities, or other mutually agreed measures and activities.

In the execution of these tasks, the Sava countries should cooperate on the basis of the *Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks* (EU Floods Directive), taking into account the *Action Programme on Sustainable Flood Protection in the Danube River Basin* and taking into account the good practices in cooperation in the field of flood protection in the Sava River Basin.

The Third and the Fourth Meeting of the Parties to the FASRB (held in Ljubljana on 1 June 2011 and in Sarajevo on 31 May 2013, respectively), recognized great efforts and work of the Sava Commission and the Parties invested so far in the field of flood management, and supported further cooperation in undertaking of all tasks envisaged by the Protocol, even before its formal entry into force.

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[1] *Sava River Basin Analysis Report: http://www.savacommission.org/dms/docs/dokumenti/documents_publications/publications/other_publications/sava_river_basin_analysis_report_high_res.pdf*

[2] *Signed in 2002, ratified in 2004*

[3] *Slovenia, Croatia, Bosnia and Herzegovina and Serbia*

[4] *Signed in 2010, ratified by Croatia and Bosnia and Herzegovina by now*

The Protocol, by its Article 6, recognises the Sava Commission as a body for the exchange of data relevant for the national Preliminary Flood Risk Assessments (PFRA) and for informing other Parties on the identified national Areas with Potential Significant Flood Risk (APSFR). It also gives the mandate to the Sava Commission to coordinate the activities on harmonisation of the APSFR shared by two or more Parties, identified by the Parties as the areas of mutual interest for flood protection.

Although the exchange of information was carried out regularly, in principle through the meetings of Permanent Expert Group for Flood Prevention (PEG FP), the PEG FP decided on its 21st meeting (held in Zagreb on 28-29 January 2013) to compile a joint report on the *PFRA in the Sava River Basin* based on the collected information from the Parties on the results of their preliminary assessment of flood risks and designation of the APSFR.

This integrated report on the *Preliminary Flood Risk Assessment in the Sava River Basin* summarizes information on methodologies and criteria used by the Parties to identify and assess significant past floods and consequences of potential future floods and designation of APSFR. It provides an overview of designated APSFR and forms a basis for harmonisation of the APSFR shared by two or more Parties, identified by the Parties as the areas of mutual interest for flood protection. The report also addresses the impacts of climate change and provides an overview of transboundary coordination and information exchange. A brief concluding remarks are provided for at the end of the report.

2 GENERAL INFORMATION ON THE SAVA RIVER BASIN

The Sava River Basin with the total area of about 97,000 km^2 is the second largest sub-basin of the Danube River Basin, with the share of 12%. Over 8 million people live in the Sava River Basin shared by Slovenia (12% of the basin territory), Croatia (26%), Bosnia and Herzegovina (39.3%), Serbia (15.5%), Montenegro (7%) and Albania (0.2%).

Rugged mountains (the Alps and the Dinarides) dominate in the upper part of the basin which belongs to Slovenia. The areas drained by right tributaries in the middle section of the Sava watercourse are also rugged. Numerous rivers run from the Dinaric Mountains in Croatia and Bosnia, having the general south-to-north direction. Particularly rugged terrains appear in Montenegro and northern Albania. The northern part of the middle and lower Sava River Basin is characterized by flat plains and low mountains. Lowland areas suitable for agricultural activities extend along the Sava River, its left-bank tributaries (within the Pannonian Plain), as well as along lower parts of its right-bank tributaries.

Alpine climate is prevailing in the upper Sava Basin within Slovenia, the moderate continental climate dominates in right tributaries' catchments within Croatia, Bosnia and Herzegovina and Montenegro, while the moderate continental (mid-European) climate primarily features in the left tributaries' catchments that belong to the Pannonian Basin. Average annual air temperature for the whole Sava Basin is about 9.5°C. Precipitation amount and its annual distribution are very variable within the basin. Average annual rainfall over the Sava River Basin is about 1,100 mm. The average evapotranspiration for the whole catchment is about 530 mm/year.

The Sava River is formed by two mountainous streams: the Sava Dolinka (left) and Sava Bohinjka (right). From the confluence of these headwaters between the Slovenian towns of Lesce and Radovljica until it joins the Danube in Belgrade (Serbia), the Sava River is 945 km long. Its average discharge at the confluence is about 1,700 m^3/s.

The most important tributaries in the upper Sava River Basin are: Kokra, Kamniška Bistrica and Savinja (at the left side) and Sora, Ljubljanica and Krka (at the right). These rivers are characterized by a torrential nature (steep channel slope, high flow velocity and rapids). Common feature of almost all right tributaries in the middle section of the Sava River is their torrential behaviour, particularly in their upper sections. River channels are often deeply cut into hard rocks, with very violent flow through gorges. These mountainous features are mostly pronounced in the Una and Drina (the largest tributary) river basins. Other significant right-bank tributaries are the Vrbas, Ukrina, Bosna, Brka and Tinja in the middle Sava section, and the Kolubara and Topčiderska rivers in the lower section. The left tributaries in the middle and lower Sava River Basin drain mostly flat areas and low hills of the Pannonian Basin. Consequently, the slopes and flow velocities are smaller and the streams are meandering. The most important rivers at the left Sava bank are the Sotla/Sutla (SI and HR), Krapina, Lonja, Ilova and Orljava (HR), and Bosut (HR and RS). These rivers encompass much smaller part of the drainage basin than the right tributaries, thus making the Sava River catchment asymmetric.

The large complex of preserved alluvial wetlands in the middle of the basin, the Srednje Posavlje, makes the Sava River Basin unique for the outstanding biological and landscape diversity, as well as for a good functioning flood retention system.

Borders of the Sava River Basin and sub-basins, topography and land cover in the basin are shown in **Maps 1**, **Map 2** and **Map 3**, respectively.

3 OVERALL APPROACH AND METHODOLOGY

The *Preliminary Flood Risk Assessment for the Sava River Basin* was prepared in accordance with the Article 6(1) of the Protocol, which states the following:

1. Each Party shall undertake Preliminary Flood Risk Assessment for its part of the Sava River Basin, taking into account the Directive 2007/60/EC.
2. In the process of Preliminary Flood Risk Assessment, the Parties shall exchange all relevant data, in principle, through the Sava Commission or bilaterally, as appropriate.
3. In the case of bilateral exchange of the relevant data from paragraph 2 of this Article, the latter shall also be delivered to the Sava Commission, without delay.
4. Based on the Preliminary Flood Risk Assessment, each Party shall, on the part of the Sava River Basin on its territory, identify those areas for which it concludes that potential significant flood risk exists or might be considered likely to occur.
5. Each Party shall, through the Sava Commission, inform the other Parties on the identified areas from Paragraph 4 of this Article.
6. The Sava Commission shall coordinate the activities on harmonisation of the areas identified pursuant to paragraph 4 of this Article shared by two or more Parties, identified by the Parties as the areas of mutual interest for flood protection.

The EU Floods Directive (2007/60/EC) in Article 4(2) stipulates that the PFRA shall be based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods, and that it shall include at least the following:

(a) maps of the river basin district at the appropriate scale including the borders of the river basins, sub-basins and, where existing, coastal areas, showing topography and land use;

(b) a description of the floods which have occurred in the past and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent and conveyance routes and an assessment of the adverse impacts they have entailed;

(c) a description of the significant floods which have occurred in the past, where significant adverse consequences of similar future events might be envisaged;

and, depending on the specific needs, it shall include:

(d) an assessment of the potential adverse consequences of future floods for human health, the environment, cultural heritage and economic activity, taking into account as far as possible issues such as the topography, the position of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas, the effectiveness of existing manmade flood defence infrastructures, the position of populated areas, areas of economic activity and long-term developments including impacts of climate change on the occurrence of floods.

The EU Floods Directive further instructs that on the basis of a Preliminary Flood Risk Assessment, those areas for which it was concluded that potential significant flood risks exist or might be considered likely to occur (i.e. APSFR) shall be identified.

The joint report was prepared on the basis of:

- The *Sava River Basin Analysis* report (ISRBC, 2009);
- Information contained in the *Preliminary Flood Risk Assessment in the Danube River Basin* report (ICPDR, 2012);

- National PFRA reports of Slovenia (MOP, 2011), Bosnia and Herzegovina[5] (HEIS, 2013), and Serbia (IJC, 2011);
- Updated information from the Parties.

This chapter further addresses the methodologies and criteria used by the Parties to identify and assess:

- Significant floods which have occurred in the past that would have significant adverse consequences were they to reoccur in the future,
- Potential adverse consequences of future floods, and
- Areas with Potential Significant Flood Risk.

3.1 SLOVENIA

The Ministry of Agriculture and the Environment completed the Preliminary Flood Risk Assessment by the deadline set in the EU Floods Directive (22 December 2011), while the results were submitted to the European Commission on 22 March 2012. The official framework for PFRA is defined in a Decree[6] published in 2010.

PFRA for the whole territory of the country was undertaken by using available/relevant information that was easy to obtain. The main source of data for definition of hazard potential was Hazard Indication Map containing data on past flooding events and flooding extent resulting from hydraulic modelling, upgraded with attributes such as maximum water levels, return period of flood, type of flood, date of commencement and duration of flood, type/degree of adverse consequences, etc.

Past flood was considered significant if it caused:

- casualties,
- damage to the property,
- damage to infrastructure, including cultural heritage.

Potential adverse consequences of future floods were assessed on the basis of the following:

- Potential flood extent was defined on a basis of the results of hydraulic modelling or, indicative flood areas defined on the basis of the highest registered water levels/discharges available in the national database and an information on the river network and topography (based on 1:25,000 scale), and the expert judgment.
- Long term developments were not considered in the PFRA, since the *Governmental decree on conditions and limitations for construction and activities in flood hazard areas*[7] requires that the future development should be kept outside of the flood hazard areas. In case of development foreseen as an extension of an existing infrastructure, measures for reducing the existing flood risk should be applied before the extension can begin.
- The recent study[8] shows that there is no concrete evidence of an influence of the climate change on the frequency of fluvial floods, and that the trends of peak discharges are slightly declining.
- There were no data with indication of possible significant pluvial and groundwater floods or floods from sewerage systems. Flood protection structures were not considered in the assessments.

[5] *Prepared only for the Federation of Bosnia and Herzegovina*

[6] *Uredbo o vsebini in načinu priprave podrobnejšega načrta zmanjševanja ogroženosti pred poplavami, Uradni list Republike Slovenije, 7/2010*

[7] *www.uradni-list.si/1/content?id=88381*

[8] *Okolje se spreminja, Podnebna spremenljivost Slovenije in njen vpliv na vodno okolje, MOP ARSO, 2010*

Potential adverse consequences of floods for human health, environment, cultural heritage and economic activities were analysed, and Index of Damage Potential of Floods was deduced by means of GIS methods, for each of the four criteria. The four types of damage potential were then aggregated, re-ranked and the areas with damage potential above the selected threshold were identified as the **Areas with Potential Significant Flood Risk**. The Government of Slovenia made final decision on designation of the APSFR on 13 February 2013. Reports on the PFRA[9] and APSFR[10] as well as maps showing results of the PFRA and APSFR[11] are available online.

3.2 CROATIA

Hrvatske Vode are responsible for undertaking the PFRA in accordance to the Article 110 of the Water Law.

The PFRA methodological approach was adjusted to the available stock of data, and the basis for the assessment encompassed: (i) the data from the CORINE Land Cover of 2006, (ii) the statistics on the population and settlements from the 2001 Census, (iii) the sites of major industrial plants and smaller settlements not visible on the Corine Land Cover, (iv) the database managed by Hrvatske Vode, and (v) the available data on the locations of waste disposal sites.

PFRA in Croatia encompassed fluvial floods, erosion due to pluvial floods, flash floods – torrents, and floods caused by artificial infrastructure (dam) failure. Data on groundwater floods were not available at the time. Watercourses within the national network of watercourses with a catchment area larger than 10 km^2 were analysed, and, exceptionally, the watercourses with smaller catchment areas, particularly in the torrential areas.

PFRA included the following:

- maps of the river basin districts including the borders of sub-basins, showing topography, land use, population density, protected areas, and flood protection structures;
- description of floods which have occurred in the past; and
- assessment of the potential adverse consequences of future floods.

Preliminary risk level within the administrative boundaries of each settlement was classified in four main categories of risk:

- High flood risk, which includes frequently flooded areas of settlements, large industrial complexes (outside of settlements), large infrastructural facilities, and waste disposal sites. This class is subdivided on:
  - ~ Very complex high flood risk – when it concerns areas under the impact of several type of floods;
  - ~ High flood risk – other areas under high flood risk;
- Moderate flood risk, which includes defended areas of settlements, large industrial complexes (outside of settlements), large infrastructural facilities, waste disposal sites, and frequently flooded agricultural areas;
- Low flood risk, which concerns defended agricultural areas and other frequently flooded areas (pastures, forests, and the like);
- Insignificant flood risk, which concerns all other remaining areas.

The above classification with sub-categorization is based on the provision of Article 115 of the Water Law, according to which the tasks of flood defence, ice defence, and protection from erosion and torrents have character of an emergency service. For that reason, it was necessary to assess those areas where an increased risk might be expected to occur due to the superimposition of

[9] *www.mko.gov.si/fileadmin/mko.gov.si/pageuploads/podrocja/voda/predhodna_ocena_poplavne_ogrozenosti.pdf*

[10] *www.mko.gov.si/fileadmin/mko.gov.si/pageuploads/podrocja/voda/porocilo_OPVP.pdf*

[11] *gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso*

adverse effects of different type of floods, already in the PFRA phase. The **Areas with Potential Significant Flood Risk** are the areas belonging to the first two classes, i.e. areas with high and moderate flood risks.

3.3 BOSNIA AND HERZEGOVINA

3.3.1 Federation of B&H

Framework for the assessment and management of flood risks and the responsibility of the Agency[12] to undertake the PFRA is set in the Regulation[13] published in 2009.

The first step for the preparation of PFRA was the development of the "Methodology of preliminary flood risk assessment for the Sava River Basin for watercourses of I category" in 2010. The following information was used for defining potential significant flood risk:

- Data on past floods collected from municipalities through a questionnaire in the first phase of the methodology preparation. Data were available for floods that occurred in 2010, 2009, 2006, 2004, 2002 and 2001 and occasional data for earlier floods.
- GIS databases on land cover (CORINE), topographic maps, flood areas (past flooding events and extent of the 20, 100 and 500-year floods), risk assessment and vulnerability data and all other available relevant information.
- Strategy for managing flood protection issues in the Sava River Basin and a proposal for activities during high water conditions.
- Evaluation of the current level of flood protection in the Federation of Bosnia and Herzegovina and designing improvement programs.
- Main preventive plan for flood defence, 2010.
- Water management Strategy of the Federation of Bosnia and Herzegovina, 2002.
- Federal operational flood defence plan, 2010.
- Cantonal Operative flood protection plans.
- Preliminary design of flood risk assessment in the Sava River Basin in the Federation of Bosnia and Herzegovina for category I watercourses.

Significant past floods are those floods that have historically had significant adverse impacts on human health, environment, cultural heritage and/or economic activity, and those which could have significant adverse effects to the same, if repeated. If data on the assessment of damages are not available, significant past (or potential future) floods include flooding which, according to the methodology, has caused (or could cause) a damage rated by a combined "index" of 100 or more. This index is obtained by combining (adding up) all adverse impacts in four categories (human health, environment, cultural heritage and economic activity) and their subcategories. The development plans were used as a basis for the assessment. An Excel-based software was developed for processing of all relevant parameters and data. Single (sub) category can amount up to 100 if certain criteria are met (e. g. 100 dwellings flooded or 300 people displaced). If a single impact is lower, the index is then adjusted linearly (e.g. for 50 dwellings the index is 50). Finally all indexes from all other categories are summed up and in case the sum reaches 100 – the flood is considered as significant.

Depth (h), flow velocity (v) and duration of flood (t) are important parameters that affect the significance of each flood but not all these data were available. The initial scoring (indexing) was made for an assumed flood depth of h=1 m, flow velocity of v=1 m/s and flood duration of 5 days (available for past floods and the value is about the average duration of a typical flood in the region). As soon as the actual data are available, a correction factor for each parameter should be

[12] *Agencija za vodno područje rijeke Save, Sarajevo*

[13] *Uredba o vrstama i sadržaju planova zaštite od štetnog djelovanja voda, Službene novine FBiH br. 26/09*

derived by a ratio of actual parameter value and "reference" values. The correction factor for 100-year flood is 0.8 and for 500-year flood 0.5. Ratio is linear for the depth and the velocity while it is logarithmic for the duration.

In order to define the **Areas with Potential Significant Flood Risk**, based on the considerations described above, the risk was classified according to the index value, as follows:

- Extremely significant > 500
- Significant 100-500
- Moderately significant 50-100
- Insignificant < 50.

3.3.2 Republika Srpska

Undertaking the Preliminary Flood Risk Assessment is responsibility of the Ministry of Agriculture, Forestry and Water Management. Deadline for its completion was 22 December 2012, but it still has not been made available in the time of preparation of this report.

3.4 SERBIA

The PFRA provisions and responsibility of the Ministry of Agriculture, Forestry and Water Management to undertake it are defined in the Water Law. The official methodology for the PFRA is defined in a Regulation[14] published in 2012.

PFRA was prepared for the whole territory of Serbia. The assessment was led by the Ministry, with participation of other responsible institutions such as public water management companies, hydrometeorological service, relevant local self-government services and scientific institutes. The PFRA started in 2009 with the preparation of a questionnaire on floods that occurred after 1965. PFRA included risk caused by fluvial floods.

The following digital data were used:

- GIS map 1:300,000 containing: administrative borders, relief, hydrography, cultural heritage, communications, settlements, hydropower plants, industrial facilities, digital terrain model;
- CORINE Land Cover 2000 (EEA);
- GIS database of indicative flood areas, encompassing the potential flood areas, which are the result of different hydraulic studies and the extent of past floods from post-flood analyses;
- levees location;
- data on population.

Digital data on economic activities, potential sources of pollution, and protected areas were not available in the first cycle of the PFRA.

Data on past floods were collected from Civil Protection units at the level of municipalities and from water management companies and Hydrometeorological Service. Only floods that caused a large-scale damage (damage which exceeds 10% of the total income of the municipality) or floods that had important social consequences (if they affected more than 100 households or 300 inhabitants, an area larger than 50 km^2, or a vulnerable facility (hospital, kindergarten, school, prison, etc.)) were identified as significant. It was assumed that all significant past floods could occur again.

Potentially flooded areas are undefended areas and areas that may be flooded in case of failure of the existing flood protection structures, with adverse consequences on human health,

[14] *Pravilnik o utvrđivanju metodologije za izradu preliminarne procene rizika od poplava, Službeni glasnik RS, 1/2012*

environment, cultural heritage and economic activity. They were assessed by taking into account the topography of the terrain, hydrology, the effectiveness of flood protection system, the position of populated areas and areas of economic activity, forecasts of long-term developments, and impact of climate change.

The **Areas with Potential Significant Flood Risk** are the areas along river sections which were exposed to a significant flood in the past and/or are endangered by a potential future flood.

The final draft PFRA and APSFR were completed at the end of 2011 while the final map showing APSFR and a table with listed boundaries of the APSFR[15] were published at the web site of the Ministry of Agriculture, Forestry and Water Management in October 2013.

[15] *www.rdvode.gov.rs/doc/6.2.1%20Znacajna%20poplavna%20podrucja%20za%20teritoriju%20Republike%20Srbije.pdf*

4 SIGNIFICANT PAST FLOODS AND POTENTIAL FUTURE FLOODS

According to *A user guide to the floods reporting schemas* (EC, 2013), floods in inland basins can have different source, mechanism and characteristics (**Table 1**).

In case of the Sava River Basin, the Parties have agreed to consider floods which are of importance for the entire basin and those which may have transboundary impact. Therefore, the PFRA for the Sava River Basin, in accordance to the Protocol, covers the issues related to floods caused by:

(a) natural phenomena such as high flows of rivers, as well as ice jamming, and

(b) artificial impacts like water discharge from reservoirs and retentions induced by dam collapsing or inadequate handling, changes in river basin, riverbeds and floodplains, etc.

Table 1: Type of floods[16]

Source	Mechanism	Characteristics
Fluvial: Flooding of land by waters originating from part of a natural drainage system, including natural or modified drainage channels. This source could include flooding from rivers, streams, drainage channels, mountain torrents and ephemeral watercourses, lakes and floods arising from snow melt. **Pluvial:** Flooding of land directly from rainfall water falling on, or flowing over, the land. This source could include urban storm water, rural overland flow or excess water, or overland floods arising from snowmelt. **Groundwater:** Flooding of land by waters from underground rising to above the land surface. This source could include rising groundwater and underground flow from elevated surface waters. **Artificial water-bearing Infrastructure:** Flooding of land by water arising from artificial, water-bearing infrastructure or failure of such infrastructure. This source could include flooding arising from sewerage systems (including storm water, combined and foul sewers), water supply and wastewater treatment systems, artificial navigation canals and impoundments (e.g., dams and reservoirs). **Other:** Flooding of land by water due to other sources.	**Natural exceedance:** Flooding of land by waters exceeding the capacity of their carrying channel or the level of adjacent lands. **Defence exceedance:** Flooding of land due to floodwaters overtopping flood defences. **Defence or infrastructural failure:** Flooding of land due to the failure of natural or artificial defences or infrastructure. This mechanism of flooding could include the breaching or collapse of a flood defence or retention structure, or the failure in operation of pumping equipment or gates. **Blockage/restriction:** Flooding of land due to a natural or artificial blockage or restriction of a conveyance channel or system. This mechanism of flooding could include the blockage of sewerage systems or due to restrictive channel structures such as bridges or culverts or arising from ice jams or landslides. **Other:** Flooding of land by water due to other mechanisms, for instance wind setup floods.	**Flash flood:** A flood that rises and falls quite rapidly with little or no advance warning, usually the result of intense rainfall over a relatively small area. **Snow melt flood:** Flooding due to rapid snow melt, possibly in combination with rainfall or blockage due to ice jams. **Other rapid onset:** A flood which develops quickly, other than a flash flood. **Medium onset flood:** An onset of flooding, that occurs at a slower rate than a flash flood. **Slow onset flood:** A flood which takes a longer time to develop. **Debris flow:** A flood conveying a high degree of debris. **High velocity flow:** A flood where the floodwaters are flowing at a high velocity. **Deep flood:** A flood where the floodwaters are of significant depth. **Other:** Other characteristics, or no special characteristics.

[16] *Source: EC, 2013*

4.1 SIGNIFICANT PAST FLOODS

Results of several important hydrological studies for the Sava River Basin show that flood waves in the basin usually appear in the autumn and in the spring. Autumn flood waves, usually caused by heavy rainfall, are of shorter duration and can have very high extreme flows. Spring flood waves are the result of snow melt, they last longer and usually do not have large maximum discharges.

Further on, the largest floods that occurred until 2010 are described in more details, in chronological order. Additionally, flood that occurred in May 2014 affecting the entire region, is described.

DRINA RIVER BASIN, OCTOBER/NOVEMBER 1896

A catastrophic flood on the Drina, Lim and Rzav rivers occurred at the end of October and continued through November 1896. Chroniclers registered that the Drina water level rose for 17 m in Višegrad, while near Zvornik it was 8.4 m above average. Recorded water level of the Drina was 1 m over fence on the famous bridge of Mehmed Paša Sokolović in Višegrad. The discharge was estimated at 9,540 m^3/s. The entire Podrinje was affected by this flood, with catastrophic consequences even along entire Sava River course in Semberija and Serbia (48,000 ha was flooded in the Mačva region). This flood had severely affected several settlements, such as Rudo, Višegrad, Skelani, Ljubovija, Francjozefsfeld (today Novo Selo), Bijeljina, Bosanska Rača and Sremska Rača. Ljubovija and Sremska Rača were displaced to present location, while Bosanska Rača has never been restored.

By constructing reservoirs of HPP Mratinje, HPP Višegrad, HPP Bajina Bašta and HPP Zvornik, probability of occurrence of such catastrophic flood was significantly decreased.

Figure 1: The 1896 Drina flood in Višegrad

SAVA, OCTOBER 1964

Flood protection system – constructed only partially, inadequate, inconsistent and vulnerable – was not able to withstand a sudden extreme inflow from the upper part of the Sava River Basin in Slovenia. Around 6,000 ha of the immediate urban area of Zagreb were flooded, as well as the settlements of Zaprešić, Samobor, Dugo Selo, and Velika Gorica. The consequences of the flood were disastrous: 17 human lives were lost, and material damage was extensive. Some 150,000 people were evacuated, and tens of thousands of people lost their homes.

Figure 2: The 1964 flood in Zagreb

SAVA AND KUPA, DECEMBER 1966

The towns of Karlovac and Sisak, as well as many settlements lying along the Kupa River between those two towns, paid a price of living in floodplains in December 1966. Around 5,500 housing units, an area of 15,600 ha at the territory of the then municipality of Karlovac, the Karlovac-Zagreb motorway, and many other roads were flooded.

Even if the Sava waters were released into the Lonjsko Polje retention area by breaching the Sava levee near Dubrovčak, due to a coincidence with the high waters of the Kupa River, the Sava spilt over the levee in Sisak, flooding the lowest parts of the town.

BOSNA, DECEMBER 1968

On 19 December 1968 large flood was recorded in the Sarajevsko Polje, when Bosna River overflowed the bridge at the gauging station in Reljevo by 30-40 cm, and washed away part of the local road on right bank in length of about 80 m.

SAVA AND BOSUT, JANUARY 1970

The middle and lower parts of the Sava River Basin in Croatia suffered great damage from the Sava flooding in January 1970. Due to a great inflow of the Sava's right-bank tributaries, the Sava flooded an area of 222,640 ha, inflicting huge damage to agricultural and urbanized areas. Since the high waters of the Sava and Bosut rivers coincided, a large part of the Bić-Bosutsko Polje was flooded as well.

SAVA, KRAPINA, KUPA AND UNA, OCTOBER 1974

The most widespread flooding in the Sava River Basin was recorded during a high water wave in October 1974, when 270,000 ha were flooded in Croatia. The flooding was caused by a simultaneous and long-lasting heavy inflow from almost the entire Sava River Basin. The Sava River spilt over and breached its levees on several sections downstream of Zagreb (on 7 locations).

The levees were blown up on 3 locations in order to release excess water into Odransko Polje, Lonjsko Polje and Mokro Polje retention areas. Despite that, numerous villages at the left and right Sava River banks (from Oborovo to Stara Gradiška) were flooded. Even though the temporary embankments (in some places as high as 120 cm) managed to protect the area beyond the Sava levees on the section from Stara Gradiška to Županja from immediate flooding, intensive rainfall and seepages beneath levees caused great damage to the agricultural areas of Crnac Polje, Jelas Polje and Bid Polje.

An area of 9,200 ha was flooded in the Krapina River Basin and 14,600 ha in the Kupa River Basin. The Krapina River and its tributaries flooded the Zlatar Bistrica, Pojatno, Bedekovčina and other smaller settlements, the Zagorje highway, and the Zaprešić-Kraljevec railroad. The Kupa flooded parts of Karlovac, Ozalj and 12 smaller settlements, while its tributaries flooded Ogulin, Slunj, Glina, Topusko and numerous smaller settlements.

Even though flood protection works had been carried out as far back as 1963 in the Una River-Sava River node and on the section of the course of the Una River towards Hrvatska Dubica, parts of the villages of Tanac and Uštica were flooded. The Una River also flooded parts of the town of Dvor.

KRAPINA, JULY 1989

In July 1989 an area of 5,600 ha was flooded, as well as the settlements of Krapina, Donja Stubica, Zabok, Marija Bistrica, Stubičke Toplice, Kupljenovo, Zaprešić, and some other smaller settlements. The Zagorje highway and a number of local roads were flooded; road traffic was virtually closed, as well as rail traffic between Zagreb and Zagorje.

UPPER SAVA RIVER BASIN, 1990

A flooding event of 1990 had major consequences for the society, covering 2/3 of the territory of Slovenia (excluding the Mura River Basin and costal area). 240,000 inhabitants were endangered, 237 relocated, 2600 evacuated, 5,231 buildings were flooded and 190 destroyed, 398 industrial facilities were flooded, 96 bridges were demolished and 280 damaged, 2,683 km of roads were damaged, 20 km of railroads were destroyed, and many landslides were initiated. The economy suffered the largest portion (28%) of the total damage. The Savinja – Sotla/Sutla area sustained the largest part of the damage (62%).

The height of this wave on the section of the Sava from Radeče (Slovenia) to Podsused (Croatia) exceeded the disastrous flood wave of 1964. Whereas the 1964 flood had had casualties and inflicted enormous material damage to Zagreb, the 1990 water wave passed through Zagreb and further downstream without any serious damage because the Sava-Odra relief channel was activated. Damage was recorded only on the stretch from the Podsused Bridge to the mouth of the Sutla River, because there was no flood protection system there.

UPPER SAVA RIVER BASIN, OCTOBER AND NOVEMBER 1998

Three events in October and November covered half of the Slovenia's territory (116 municipalities), excluding the Mura River Basin, costal area and part of the Gorenjska area. The direct damage amounted to 173 million EUR and the Savinja – Sotla/Sutla area suffered the largest share (44%).

KUPA, NOVEMBER 1998

The flood protection solution in the Kupa River Basin is integral part of a comprehensive flood protection solution in the Srednja Posavina. The constructed structures provide protection from mere 5-year high water to 50-year high water. Due to occurrence of higher water flows, the Kupa River flooded urbanized and agricultural areas (12,000 ha) in Croatia in November 1998.

TAMNAVA, UB AND GRAČICA, JULY 1999, MARCH 2006, MARCH 2009

The Tamnava River and its tributaries in the Kolubara River Basin had frequently flooded the adjacent land due to a lack of flood protection system. Three floods were identified as significant according to the adopted criteria. In July 1999, the Tamnava, Ub and Gračica flooded about 6,000 ha and 480 households with about 2,050 inhabitants. In March 2006, the Tamnava, Ub and Gračica flooded 5,600 ha and 129 households. In March 2009, the Tamnava and Ub flooded 3,000 ha and 280 households with 1,100 inhabitants. Larger damages were avoided by retaining water in a fishpond at the Ub River. Frequent flooding of the Tamnava, Ub and Gračica initiated reconstruction of the flood protection system along these rivers.

KOLUBARA, JUNE 2001

Flood of June 2001 caused inundation of 3,800 ha with 110 households and a prison due to a lack of flood protection system in the middle section of the Kolubara River.

JADAR AND LJUBOVIĐA, JUNE 2001

In June 2001, the Jadar River (right-bank tributary of the Drina) and its tributaries flooded an area of 5,500 ha and 700 households.

The Ljubovića River (right-bank tributary of the Drina) flooded an urban area with 515 households and 2,100 endangered inhabitants (925 of which were evacuated), as well as kindergarten, primary and secondary schools.

SAVA, APRIL 2006

In April 2006, the Danube backwater caused flooding of about 60 ha at the right Sava bank. 334 buildings with about 1,455 endangered inhabitants, important economic facilities and infrastructure (Belgrade Fair, railway station, important city roads) were flooded at the Sava mouth in Belgrade.

UPPER SAVA RIVER BASIN, SEPTEMBER 2007

Large storms persisted for a long time in September 2007 causing extremely large flows of the small and medium-sized rivers. Torrential floods were recorded in 1/3 of the Slovenia's territory. Direct damage amounted to 200 million EUR, 38% of which in water infrastructure. 83% of the total damage was in the Gorenjska and Savinja – Sotla/Sutla area. 4,329 residential buildings, 979 commercial buildings, 61 public institutions, 192 companies, 347 km of national and 1,591 local roads, 147 bridges, 17 km of water supply network, 7 km of the electrical network and 48 water reservoirs were flooded; and 432 landslides were triggered thus endangering 29 buildings.

UPPER SAVA RIVER BASIN, DECEMBER 2009

The flood of December 2009 covered 1/3 of the Slovenia's territory, causing damage of 25 million EUR, 72% of which was in water infrastructure. 93% of the total damage was in the area of the Upper Sava and Soča[17].

EASTERN LEFT-BANK TRIBUTARIES OF THE SAVA RIVER, MAY/JUNE 2010

The catastrophic floods in May/June caused large damages to agriculture, livestock production, infrastructure, personal property and property of local self-government units in eastern and central parts of Croatia. The economy of an area, and of the country as a whole, depends on the proceeds from farming, including livestock and fruit production. Since floods, hail and thunderstorms destroyed most crops and pastures, it was estimated that financial consequences would be felt more than a year afterwards. 420 houses, cellars and yards were flooded; 524 houses were directly threatened and damaged; 105 families were evacuated, and, where appropriate, also

[17] *The Soča River does not belong to the Sava River Basin*

movables and domestic animals (poultry, pigs, cattle). The evacuated population (and animals) were cared for and provided with temporary accommodation. Wells and other water sources were polluted, so potable water had to be delivered by water trucks. Floods blocked road traffic on county and local roads, which impeded the delivery of food and other livelihood products and provision of health service and potable water, as well as public transport.

KOLUBARA, JUNE 2010

Flood of June 2010 covered 2,000 ha and 135 households due to a lack of flood protection system in the lower section of the Kolubara River.

SAVA AND WESTERN LEFT-BANK TRIBUTARIES, SEPTEMBER 2010

Outstanding long-term rainfall caused torrential, river and karst floods in the 3/4 of the Slovenia's territory (170 municipalities). Direct damage amounted to 188 million EUR, 62% in water infrastructure, 35% of which in the Sava floodplains in its upper section.

At the Sava section in Croatia upstream of Sisak, the water wave had the occurrence of a 100-year return period. High flows also occurred along the western left-bank Sava tributaries. In total, 900 residential buildings were flooded, 257 people were evacuated from flood-affected areas in Croatia and, where appropriate, movables and domestic animals as well (poultry, pigs, cattle and horses). From the area of the Nature Park "Lonjsko Polje" 600 cattle were evacuated, mostly native horse species. Municipality water wells and other water sources were polluted, so water trucks delivered potable water. Many roads were closed. Since Zagreb is one of the most traffic-heavy nodes in the country, closing down of the roads caused enormous material losses and great reparation costs.

KUPA AND UNA, DECEMBER 2010

At the Kupa and Una sections in Croatia, discharge peaks with return periods between 10 and 50-year occurred in December 2010. Many roads at the Karlovac and Sisak-Moslavina counties were flooded, as well as parts of the Nova Drenčina, Lužice-Letovanić, Stari Brod and Žažina settlements and agricultural land along the Kupa River.

DRINA AND TRIBUTARIES, DECEMBER 2010

In the Drina River Basin an extreme flood event occurred in the end of November and the beginning of December. Flood waves on the Drina and its tributaries were induced by extreme rainfalls in Montenegro and east Herzegovina, where 100-200 mm of rain fell in 3 days. Flood waves on the Drina tributaries (Piva, Tara, Ćehotina, Lim and Jadar) and the main course were exceptional, such that hydropower reservoirs could not retain them. A new maximum was recorded on 3 December 2010 at Radalj, the most downstream gauge station on the Drina River. The Drina River flooded about 1,000 households at the right bank, downstream of the Ljubovija settlement. About 1,400 inhabitants were evacuated from this area. Consequently, flood wave also occurred at the downstream section of the Sava River in Serbia, where emergency flood defence was declared at the beginning of December.

The Lim River flooded 150 households in the Prijepolje town.

SAVA RIVER BASIN, MAY 2014

The flooding in Serbia, Bosnia and Herzegovina and Croatia, which occurred in the middle of May 2014 after a three-months amount of rain fell onto the region in just three days, had devastating impacts. The heaviest rainfall since records began 120 years ago caused an extreme increase of water levels in the rivers, some exceeding ever recorded maximums.

The floods have firstly occurred along the rivers with smaller catchments. At the left Sava bank, floods occurred in the Orljava River basin, where 500 households were flooded in the Pleternica settlement and the surroundings, and in the Ilova River basin where over 100 houses were flooded.

Right tributaries of the Sava River – the Bosna, Vrbas and Una caused flooding and great loss in the area. Additional damage was caused by landslides. Floods had particular devastating impact in the towns and villages along the Bosna River (Zavidović, Maglaj, Doboj, etc.). The Drina River basin suffered from flooding and landslides causing extreme damage. Several settlements in the Kolubara River basin were flooded, where the town of Obrenovac suffered the most after it was impounded by water several meters deep in the city centre.

Enormous inflow from the right-bank tributaries lead to a fast increase of the Sava water levels as of May 15, in the bordering sections between Bosnia and Herzegovina and Croatia and in Serbia. On May 17, the Sava River breached left-bank levee at two locations, flooding several settlements and agricultural land in eastern Croatia. The downstream breach occurred just about 5 km and the upstream breach near the Rajevo Selo 25 km from the state border, so the flood water progressed over flat areas towards lower terrain in Serbia and flooded agricultural areas and one village there as well.

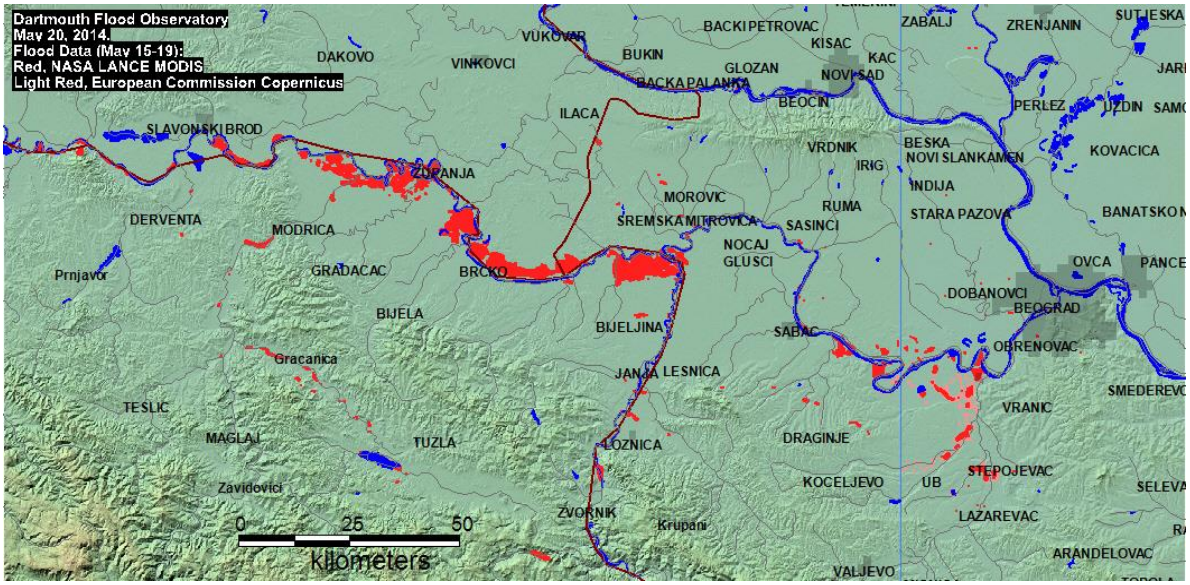
Right-bank levee could not withstand high water pressure of the Sava River either. In period May 17-18 levees burst at several locations in Bosnia and Herzegovina, causing flooding of large areas in the Odžačka Posavina, Srednja Posavina and in Semberia. On May 19 the levee breached in Serbia just upstream of Obrenovac, endangering the town once again.

1.6 million people were affected by floods in Serbia (32,000 evacuated), 1.5 million in Bosnia and Herzegovina (35,000 evacuated), while in Croatia the flood affected smaller area and about 40,000 people (18,000 evacuated). Besides the evacuated, many more people left the area by themselves.

24 people died in floods and one due to landslides in Serbia. Reported number of deaths in Bosnia and Herzegovina was 23. Two people died in floods in Croatia.

Besides the devastating effects of flood water, additional danger presented flooding of the areas suspected to contain mines in Bosnia and Herzegovina and in Croatia, potential spread and dislocation of mines and unexploded ordnance, risk of water contamination, epidemics and water borne diseases, as well as landslides which continued to pose further risk in hilly areas after the flooding.

Area affected by flooding (Source: Al Jazeera Balkans)



Flooded area 15-19 May (Source: Dartmouth Flood Observatory)

Doboj, Bosnia and Herzegovina

Županjska Posavina, Croatia

Obrenovac, Serbia

Levee breach

Figure 3: May 2014 flood in the Sava River Basin

4.2 POTENTIAL ADVERSE CONSEQUENCES OF FUTURE FLOODS

Floods had occurred in the past and will continue to occur in the future in the Sava River Basin, both along natural river sections and in case of structure overtopping or failure. Important flood prone areas of the Sava River, as identified in the *Sava River Basin Analysis* report (2009) are listed in **Table 2**. Besides, the Parties have assessed the potential adverse consequences of future floods for human health, the environment, cultural heritage and economic activity, taking into account as far as possible issues such as the topography, the position of watercourses and their general

hydrological and geomorphological characteristics, including floodplains as natural retention areas, the effectiveness of existing manmade flood defence infrastructures, the position of populated areas, and areas of economic activity.

Slovenia prepared flood warning map showing the extent of potential floods, classified as common, rare or very rare floods. The description of these areas along the Sava River and its tributaries, based on the map provided in the national report on PFRA and online, is given below.

In **Croatia**, the most prone to flooding are alluvial lowlands of the Sava, Kupa and Una rivers and their tributaries, as well as hilly and mountainous areas with high rainfall intensities. The most endangered are those areas where flood protection system has not been completed yet.

Bosnia and Herzegovina prepared maps showing the areas in Federation of B&H which may potentially be flooded in future, as defined by the *Federal action plan for flood defence*[18]. Description of these areas, on the basis of the maps provided in the national report on PFRA, is given below.

Serbia prepared map showing the areas which may potentially be flooded along the Sava, Bosut, Drina, Kolubara and its tributaries. Description of these areas is given in the national report on the PFRA and is presented below.

4.2.1 The Sava River

Eastern of Ljubljana, the Sava flows through a 90 km long gorge where no significant consequences of potential future floods are expected. Along the sections Tacen-Šentjakob-Beričevo at the territory of Ljubljana, and from Dolsko to Litija, very rare to rare floods can be expected in the lower parts of Ljubljana, agricultural land and smaller settlements. There are two hydropower plants (Mavčice and Medvode) at this section. The Sava River then flows through another gorge, and near the Radeče settlement enters a narrow floodplain with several settlements which may potentially be flooded. There are three hydropower plants (Vrhovo, Boštanj and Blanca) at this section. Agricultural land and smaller settlements in wide floodplains of the Krško Polje, downstream of the Krško settlement, are prone to frequent flooding. Flooding can also have high adverse consequences in the area downstream of Brežice to the Sotla/Sutla mouth (Brežiško Polje, Čateško Polje, and Dobovsko Polje), in case of a levee failure.

At the section from the Sotla/Sutla mouth to Podsused at the upstream edge of Zagreb, flood protection system has not been completed and therefore 57 km^2 is endangered by flooding.

The City of Zagreb is protected by levees designed against 1,000-year flows and additionally by the Sava-Odra relief channel, however, it may potentially be flooded in case of a structure failure or overtopping. Parts of Zagreb are at risk from torrents from the Medvednica Mountain even though 19 mountain retarding basins have been constructed. Zagreb is protected from torrential streams only from floods of 20 to 50-year return periods.

In the middle and lower sections, the Sava has been confined by embankments at most of its length, however, floods may occur in case of the defence exceedance or failure. There are several important towns in this area, such as Sisak, Bosanska Gradiška, Bosanski Brod, Slavonski Brod, Brčko, Sremska Mitrovica, Obrenovac and Belgrade, as well as industry, infrastructure, cultural heritage, agricultural land, and nature protection areas. Most of the area is protected against 100-year high flows. At this section, potentially the most endangered areas are those protected by structures which do not meet the required safety level, such as:

- Old levees built under different protection criteria which do not have the required freeboard above Q100 flows – along shorter sections of the left-bank Sava levee from Dubrovčak to Trebež, parts of the left Sava levee protecting Biđ-bosutsko Polje, shorter

[18] *Federalni operativni plan odbrane od poplava*

sections of the right-bank Sava levee upstream of Sisak as well as between the Drina River mouth and Šabac;

- Right levee in the Odžačka Posavina region, which is affected by animal shelters and there are also mines in the body of levee remaining from the war;
- Quay walls and levees in the central Belgrade area, which crest level is below the design protection level due to urban planning requirements.

4.2.2 Tributaries to the Sava River

The **Ljubljanica River** valley is highly prone to flooding with high potential adverse consequences at the territory of the Ljubljana city, including impact on the inhabitants, economy and infrastructure. The area is protected from flooding by levees and a relief channel, but the city is potentially endangered in case of overtopping or structure failure.

The **Savinja River** and its tributaries endanger the town of Celje, in case of overtopping or structure failure.

In case of a natural exceedance of the main channel, the **Krka River** may potentially flood small settlements, agricultural land and woods in the Šentjernej area.

The **Krapina River** dominantly endangers agricultural land, in case of a potential overtopping or failure of levees.

The **Lonja River** and its tributaries the Česma and the Ilova rivers endanger many settlements (Ivanić Grad, Vrbovec, Dugo Selo, Bjelovar, Čazma, Daruvar, Lipik, Pakrac, Garešnica, etc.) in case of a potential failure of the flood protection system. Torrential floods potentially endanger hilly parts of the catchment.

The **Orljava River** potentially endangers settlements Pleternica, Požega, Kutjevo, etc. in case of a flood protection system failure. Torrential floods potentially endanger hilly parts of the catchment.

Transboundary **Bosut River** may potentially flood smaller settlements and agricultural land.

KUPA RIVER BASIN

The **Kupa River** flooded before and may flood the adjacent land in the future, even if there is flood protection system consisting of levees (which are not continuous) and a retention basin with relief channel near the Karlovac town. Karlovac and Sisak have the highest risk of flooding, while the Kupa River also endangers many smaller settlements and agricultural land between those two large towns in Croatia, both along the natural river sections and in case of structure overtopping or failure.

Smaller settlements in the **Dobra River Basin** are inadequately protected from torrential mountain streams.

UNA RIVER BASIN

Floods may potentially occur at the:

- **Una River**, in a wider area of the Bihać municipality (including Kulen Vakuf and Bihać), the Bosanska Krupa municipality (from Bosanska Krupa to the downstream end of the Otoka settlement);
- **Sana River**, in the Sanski Most, as well as along the tributary **Sanica** in the Sanica settlement.

VRBAS RIVER BASIN

The **Vrbas River** may potentially flood the area in the Gornji Vakuf, Bugojno and Donji Vakuf municipalities.

BOSNA RIVER BASIN

Floods may potentially occur at the:

- **Bosna River**, in the Sarajevo urban area and downstream of Modriča; and at its tributaries: the **Usora River**, downstream of the Kalošević settlement, and the **Spreča River** downstream of the Modrac dam;

TINJA RIVER BASIN

The **Tinja River** may potentially flood the area downstream of Previlje to Gornji Hrgovi settlement.

DRINA RIVER BASIN

Floods may potentially occur at the:

- **Drina River**, which endangers the Goražde municipality in Bosnia and Herzegovina, as well as a large area in Serbia downstream of HPP Zvornik, including towns of Zvornik, Banja Koviljača, and Loznica, many smaller settlements and agricultural land;
- Natural river sections and protected sections in case of structure overtopping or failure along the downstream courses of the **Pilica** and **Jadar** rivers, as well as along the **Likodra River** within the town of Krupanj.

KOLUBARA RIVER BASIN

The **Kolubara River** and the tributaries (**Vraničina**, **Lukavica**, **Toplica**, **Ribnica**, **Turija**, **Beljanica**, **Barajevska**, **Baćevačka**, **Tamnava**, **Ub**, **Gračica**, **Ljig**) may potentially flood over 155 km² along natural river sections or in case of structure overtopping or failure. The towns of Valjevo, Lazarevac and Obrenovac have the highest risk, while the floods also endanger many smaller settlements and agricultural land.

Table 2: Important flood prone areas of the Sava River[19]

Country code	Flood prone area	Watercourse	Bank (L/R)	Area (km²)	Protected (Y/N)	Comment
SI	Tacen – Šentjakob – Beričevo	Sava	L/R	12	Y/N	Q_{100}
	Dolsko – Litija	Sava	L/R	13	N	
	Krško Polje	Sava	L/R	17	Y/N	Q_{100}
	Brežiško Polje	Sava	L/R	12	N	
	Čateško Polje	Sava	L/R	3	Y/N	Q_{100}
	Dobovsko Polje	Sava	L/R	11	N	
HR	Grad Zagreb (Sotla/Sutla mouth – Podsused)	Sava	L/R	57	N	
	Grad Zagreb	Sava	L/R	82	Y	Q_{1000}
	Odransko Polje	Sava	R	289	Y	Q_{100}
	Sisačko – Banijsko područje	Sava	R	152	N	Zelenik retention area
	Sisačko – Banijsko područje	Sava	R	73	Y	Q_{100}
	Črnec Polje	Sava	L	57	N	Žutica retention area
	Črnec Polje	Sava	L	294	Y	Q_{100}
	Lonjsko Polje	Sava	L	390	N	Retention area (Lonjsko Polje, Mokro Polje, Opeka and Trstik)

[19] *Source: Sava River Basin Analysis report*

Country code	Flood prone area	Watercourse	Bank (L/R)	Area (km²)	Protected (Y/N)	Comment
	Lonjsko Polje	Sava	L	366	Y	Q_{100}
	Crnac Polje	Sava	L	177	Y	Q_{100}
	Jelaš Polje	Sava	L	203	Y	Q_{100}
	Biđ-bosutsko Polje[20]	Sava	L	1,127	Y	Q_{100}
BA (RoS)	Dubička ravan	Sava, Una	R	68	Y	Q_{100}
	Lijevče Polje	Sava, Vrbas	R	210	Y	Q_{100}
	Srbačko – Nožička ravan	Sava, Vrbas	R	30	Y	Q_{100}
BA (FB&H, RoS)	Ivanjsko Polje	Sava	R	150	Y	Q_{100}
BA (FB&H)	Odžačka Posavina	Sava, Bosna	R	87	Y	Q_{100}
	Srednja Posavina – Orašje	Sava, Tinja	R	131	Y	Q_{100}
BA (RoS)	Srednja Posavina	Sava, Tinja	R	92	Y	Q_{100}
	Semberija	Sava, Drina	R	153	Y	Q_{100}
RS	Gornji Srem[21]	Sava, Eastern Periphery Canal	L	564	Y	Q_{100}
	Sremska Mitrovica	Sava, Eastern Periphery Canal	L	12	Y	Q_{100}
	Hrtkovci – Sremska Mitrovica	Sava	L	16	N	
	Hrtkovci	Sava	L	12	Y	Q_{100}
	Klenak – Hrtkovci	Sava	L	11	N	
	Klenak	Sava	L	5	Y	Q_{100}
	Kupinovo – Klenak	Sava	L	107	N	
	Kupinovo II	Sava	L	13	N	Ongoing construction – new levee not finished
	Kupinovo I	Sava	L	6	Y	Q_{100}
	Donji Srem	Sava, Nova Galovica	L	121	Y	Q_{100}
	Novi Beograd	Danube, Sava, Nova Galovica	L	24	Y	Q_{100}
	Mačva	Sava, Drina	R	437	Y	Q_{100}
	Orasac	Sava, Dobrava	R	3	Y	Q_{100}
	Mrdjenovac – Ladjenik	Sava, Dobrava	R	17	Y	Q_{100}
	Provo – Orlača	Sava	R	16	Y	Q_{100}
	Obrenovac	Sava, Kolubara, Periphery Gravity Canal	R	96	Y	Q_{100}
	Mislodjin Barič	Sava, Kolubara, Barička	R	5	Y	Q_{100}
	Mali Makiš	Sava	R	3	Y	Q_{100}
	Veliki Makiš – Ada Ciganlija	Sava, Ostružnička, Železnička, Topčiderska	R	31	Y	Q_{100}
	Beograd	Sava, Topčiderska	R	2	Y	Q_{100}

[20] *Inclusive the flood prone area of the tributary Bosut River in Croatia*

[21] *Inclusive the flood prone area of the tributary Bosut River in Serbia*

5 AREAS WITH POTENTIAL SIGNIFICANT FLOOD RISK

On the basis of the national Preliminary Flood Risk Assessments, the Parties identified those areas for which they concluded that potential significant flood risks exist or might be considered likely to occur. National methodologies for identification of the APSFR are presented in **Chapter 3**.

The countries had different approaches in mapping the APSFRs. Slovenia, Croatia and Bosnia and Herzegovina used polygons to mark the areas identified as APSFR. Serbia presented APSFR as lines and points. **Map 4** shows locations of the Areas with Potential Significant Flood Risk (APSFR) as identified by the Parties. The map shows the status as of April 2014.

5.1 SLOVENIA

Slovenia used polygons to roughly mark parts of settlements or objects of economic activities that are identified as APSFR. There are 42 APSFR in the Sava River Basin in Slovenia that can be flooded by a single river or several rivers that confluence within the APSFR.

These areas are threatened by the Sava, Savinja, Sotla/Sutla, Ljubljanica, Krka, and some other first and second order tributaries of the Sava River with smaller catchments. Total size of the area with potential significant flood risk is about 82 km^2.

Among the 42 identified, several APSFR are at the transboundary rivers – the Sava and the Sotla/Sutla rivers, which required coordination with the neighbouring Croatia.

5.2 CROATIA

1688 APSFR were identified in the part of the Sava River Basin belonging to Croatia. Each of the 1688 polygons represents territory of one settlement, as the smallest administrative unit. The APSFRs cover the area of 14,300 km^2, which is endangered by:

- larger rivers such as the:
  - Sava,
  - Sotla/Sutla, Krapina, Lonja and its tributaries Glogovnica and Česma, Ilova, Orljava, Bosut (at the left Sava bank),
  - Kupa/Kolpa and its tributaries Dobra, Korana and Glina, and the Una (at the right Sava bank),
- rivers with smaller catchments,
- erosion due to pluvial floods,
- flash floods – torrents, and
- floods caused by artificial infrastructure (dam) failure.

Large number of settlements is threatened by transboundary rivers – the Sava, Sotla/Sutla, Kupa/Kolpa, Una and Bosut. There are APSFR along the entire Sava River section in Croatia, at both river banks. As for the other transboundary rivers, there are only several settlements identified as APSFR along their banks.

5.3 BOSNIA AND HERZEGOVINA

Federation of B&H identified 68 APSFR within the Sava River Basin on its territory, which have significant or extremely significant flood risk. They cover total area of 586 km^2.

The largest area is threatened by the Sava River and its first and second order tributaries: Glina, Una, Sana, Vrbas, Bosna, Lašva, Krivaja, Spreča, Tinja, Drina, Prača and Drinjača, but APSFR are identified in the catchments of smaller rivers as well.

As for the transboundary rivers, APSFR are identified along the Sava, Una, and Glina rivers.

There were no information on the APSFR in the Republika Srpska at the time of preparing of this report.

5.4 SERBIA

Serbia identified APSFR at sections of 25 rivers, including the Sava (the entire section in Serbia) and its direct tributaries Bosut, Drina (and its tributary the Lim) and Kolubara. APSFR are also identified along the rivers with smaller catchments. APSFR were mapped as lines along 20 rivers, and in case of other 5 rivers that endanger individual settlements – APSFR were mapped as points.

Over 730 km of rivers endanger the riparian land, and it was assessed that the Sava, Bosut, Drina and the Kolubara with its tributaries may potentially flood the total area of about 2,250 km^2.

Four among the 25 rivers along which the APSFR were identified are transboundary rivers: Sava, Bosut, Drina and Lim.

6 ADDRESSING THE IMPACTS OF CLIMATE CHANGE

The *Protocol on flood protection to the FASRB* acknowledged the likely consequences of climate change on the water regime in the Sava River Basin and the need of effective adaptation measures. Besides, the EU Floods Directive stated that the Preliminary Flood Risk Assessment shall, among other things, particularly take into account the impact of climate change on the occurrence of floods. However, even the EC Guidance document No. 24 recognised that "there are likely to be challenges and limitations on the degree of consideration of climate change in undertaking the Preliminary Flood Risk Assessment, particularly in the first cycle, given the qualitative rather than quantitative information that may be available or readily derivable. This knowledge is foreseen to be improved in the second cycle (after the first flood maps and Flood Risk Management Plans)."

For the next planning cycle, the Parties will have available results of at least two projects related to climate change in the Sava River Basin:

- **"Pilot project on climate change adaptation: Building the link between Flood Risk Management planning and climate change assessment in the Sava River Basin"** (funded by the UNECE, 2010-2013), which has provided outcomes regarding the possible climate change impacts on the flood management as well as some recommendations on possible adaptation measures.
- **"Water and Climate Adaptation Plan for the Sava River Basin"** (WATCAP) project administered by the World Bank (2010-2014). It has provided a hydrologic model used for simulation of climate change scenarios and results of simulations, and guidance on flood protection, as well as the Water and Climate Adaptation Plan for the Sava River Basin.

The final results of both projects represent a strong basis for further elaboration of climate change impacts on flood management in the Sava River Basin. Namely, both projects concluded that winter precipitation would increase, the highest increase being in the north-western part of the basin. Even in current climate this part of the basin receives the highest precipitation. Considering that the most significant past floods in the basin had occurred in winter due to high precipitation, with a fact that temperature increase is envisaged (over the entire year) as well, more frequent floods may be expected in case of high rainfall in winter or due to faster snow melt.

Therefore, it is necessary to continue monitoring of occurrence of floods in the Sava River Basin in a following period. In order to provide a consistent and comparable set of data for all events, the Sava Commission prepared a common database for gathering information on past floods and on floods that will occur and which will be considered as "new old" floods in the next implementation cycle. This would improve the analysis of trends of changing flood patterns.

7 TRANSBOUNDARY COORDINATION AND INFORMATION EXCHANGE

According to the *Protocol on Flood Protection to the FASRB,* on the course of undertaking the Preliminary Flood Risk Assessment at the national level, the countries in the Sava River Basin shall exchange all relevant data, and inform the other Parties on the identified Areas with Potential Significant Flood Risk, through the Sava Commission or bilaterally.

Legal means for bilateral cooperation in water management between the Parties to the FASRB are set by the:

- *Agreement between the Government of the Republic of Croatia and the Government of the Republic Slovenia on the Regulation of Water Management Relations* (entered into force on March 19 1998),
- *Rulebook of the Permanent Croatian – Slovenian Commission for water management* (entered into force on March 19 1998),
- *Agreement between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on cooperation on protection against natural and civic disasters* (entered into force on 1 November 1999),
- *Agreement between the Council of Ministers of the Bosnia and Herzegovina and the Government of the Republic of Croatia on Water Management Relations* (entered into force on 31 January 1997),
- *Agreement between the Council of Ministers of the Bosnia and Herzegovina and the Government of the Republic of Croatia on cooperation on protection against natural and civil disasters* (signed on 1 June 2001).

In addition, Croatia and Montenegro regulated their cooperation in water management by an *Agreement between the Government of the Republic of Croatia and the Government of Republic of Montenegro on water management relations,* which entered into force on 12 April 2008.

Slovenia and Croatia have stated that they agreed on the APSFR on bilateral level at the meeting of *Permanent Croatian – Slovenian Commission on Water Management* held in March 2014.

There are, however, no agreements on bilateral cooperation in the field of water management between Croatia and Serbia, or Bosnia and Herzegovina and Serbia. Therefore, cooperation of the Parties on the Preliminary Flood Risk Assessment, as well as on other activities in line with the Protocol, are conducted through the Sava Commission. Also, there is no agreement on bilateral cooperation of Bosnia and Herzegovina or Serbia with Montenegro.

Relevant information and data on the PFRA and APSFR have been exchanged through work of experts coming from the competent authorities of the Parties and several meetings of the Sava Commission's Permanent Expert Group for Flood Prevention and Ad hoc GIS Expert Group. This report sums up the results of such exchange, for the part of the Sava River Basin at the territory of the Parties.

Past floods which were significant for the Sava River Basin and potential adverse consequences of future floods are described in **Chapter 4** of this report. Information on the APSFR identified by the Parties is contained in **Chapter 5** and their location is shown in **Map 4**. The map shows status as of April 2014, when PFRA and APSFR identification have been completed by Slovenia, Croatia, Bosnia and Herzegovina (FB&H) and Serbia, while information from the Republika Srpska has not been available at the time of completion of this report.

8 CONCLUSIONS

The *Protocol on Flood Protection to the FASRB* obliged the Parties to cooperate on undertaking of Preliminary Flood Risk Assessment. Even if the Protocol has not formally entered into force by the time of completion of this report, the Parties to the FASRB encouraged and supported further cooperation in undertaking of Preliminary Flood Risk Assessment at their Third and the Fourth Meeting.

This report is an evidence of such cooperation and it supports the exchange of information relevant for the Preliminary Flood Risk Assessment and sharing information on the identified Areas with Potential Significant Flood Risk, which took place in the meetings of the Sava Commission's Permanent Expert Group for Flood Prevention, as well as of the Ad hoc GIS Expert Group.

The countries have conducted the PFRA in accordance to their national legislation, which takes into account provisions of the EU Floods Directive 2007/60/EC. This report summarises methodologies used at national level to assess significant floods which had occurred in the past and criteria for evaluation of their significance, to assess floods which may occur in the future and have potential adverse consequences, and to identify Areas with Potential Significant Flood Risk.

Significant floods which had occurred in the past and potential future floods, which had or may have adverse consequences for human health, the environment, cultural heritage and economic activities, that are of importance for the entire Sava River Basin are described in the report. Summary information on the APSFR identified at national level is also provided, with special attention on the APSFR identified along transboundary rivers in the Sava River Basin.

The impacts of climate change are addressed in a separate chapter, which summarises recent activities and projects related to climate change assessment that are implemented at the Sava River Basin level. Description of international coordination between the Parties, both at bilateral and multilateral levels is provided as well.

The report is accompanied with maps showing sub-basins above 1,000 km^2 and several smaller size sub-basins of importance at the basin level, topography and land cover in the Sava River Basin, as well as the Areas with Potential Significant Flood Risk as identified by the Parties.

The report and the enclosed maps send an important message to the public and stakeholders on the areas which have the highest risk of flooding and present a good basis for preparation of the *Flood Risk Management Plan in the Sava River Basin,* which is envisaged by the *Protocol on Flood Protection to the FASRB.*

REFERENCES

EC (2009), Guidance document No. 24, River basin management in a changing climate, Common implementation strategy for the Water Framework Directive (2000/60/EC), Technical Report - 2009 - 040, European Communities

EC (2013), A user guide to the floods reporting schemas, Technical support in relation to the implementation of the Floods Directive (2007/60/EC), European Commission – DG Environment, Report Ref: V5.0 June 2013

EU (2007), Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, Official Journal of the European Union L288, 6.11.2007, 27-34

HEIS (2013), Preliminarna procjena poplavnog rizika na vodotocima I kategorije u FBiH, Institut za hidrotehniku Sarajevo, Sarajevo

ICPDR (2012), Preliminary Flood Risk Assessment in the Danube River Basin, International Commission for the Protection of the Danube River, Vienna

IJC (2011), Preliminarna procena rizika od poplava na teritoriji Republike Srbije – 3. faza, Institut za vodoprivredu "Jaroslav Černi", Beograd

ISRBC (2009), Sava River Basin Analysis Report, International Sava River Basin Commission, Zagreb

ISRBC (2010), Protocol on Flood Protection to the Framework Agreement on the Sava River Basin, International Sava River Basin Commission

MOP (2011), Predhodna ocena poplavne ogroženosti Republike Slovenije, Ministrstvo za okolje in prostor, Ljubljana

MOP (2013), Poročilo o določitvi območij pomembnega vpliva poplav v Republiki Sloveniji in spremljanju aktivnosti obvladovanja poplavne ogroženosti na območjih pomembnega vpliva poplav, Ministrstvo za okolje in prostor, Ljubljana

MAPS

Sub-basins in the Sava River Basin

MAP 1

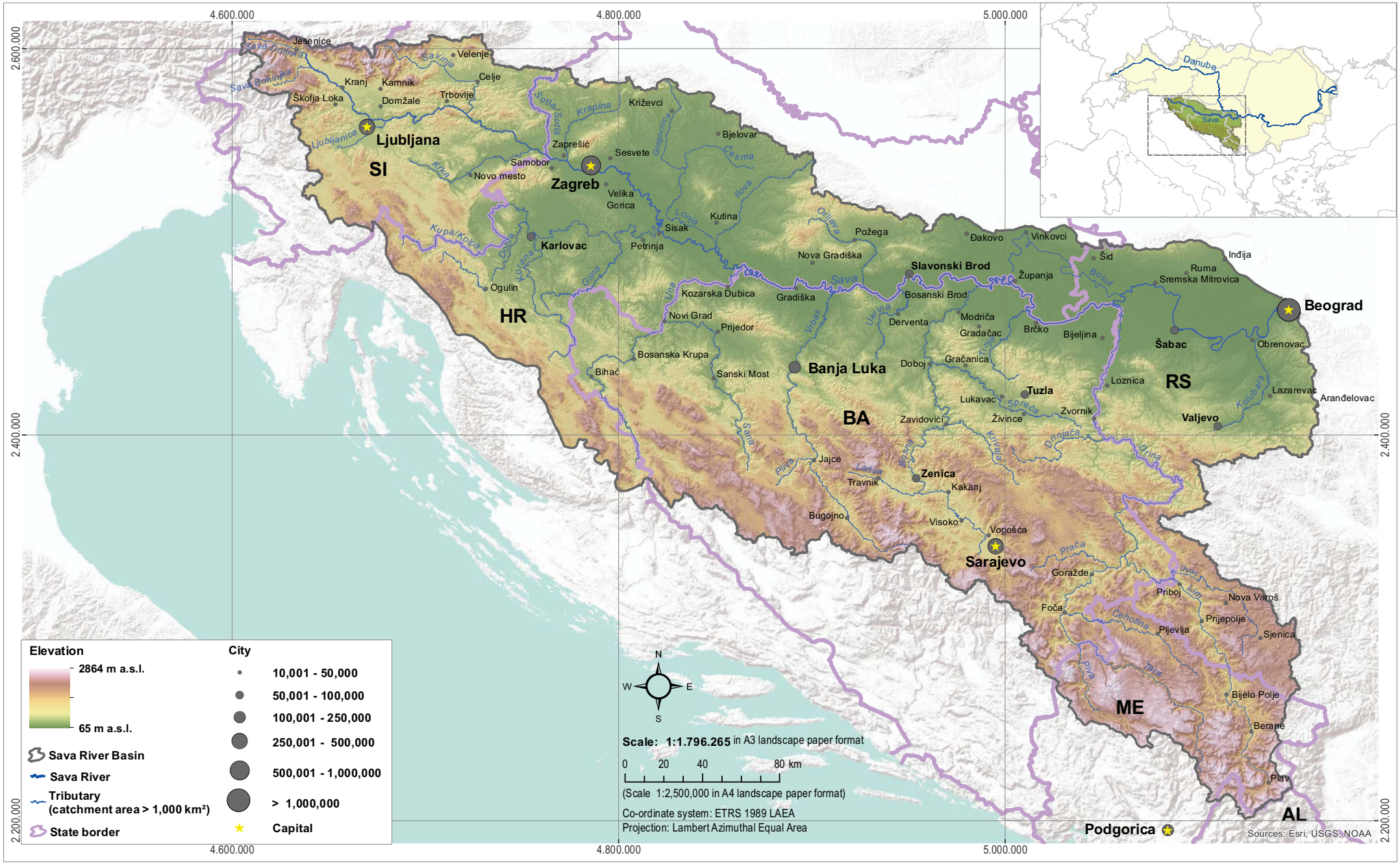
This product is based on national information provided by the Parties to the FASRB (SI, HR, BA, RS) and ME.
Shuttle Radar Topography Mission (SRTM-3) from USGS Seamless Data Distribution System was used as topographic layer.
The boundaries and names shown and designations used on this map do not imply official endorsment or acceptance by the ISRBC.

PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

ISRBC Secretariat, 2014

Topography of the Sava River Basin

MAP 2



This product is based on national information provided by the Parties to the FASRB (SI, HR, BA, RS) and ME.
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PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

ISRBC Secretariat, 2014

Land cover in the Sava River Basin

MAP 3

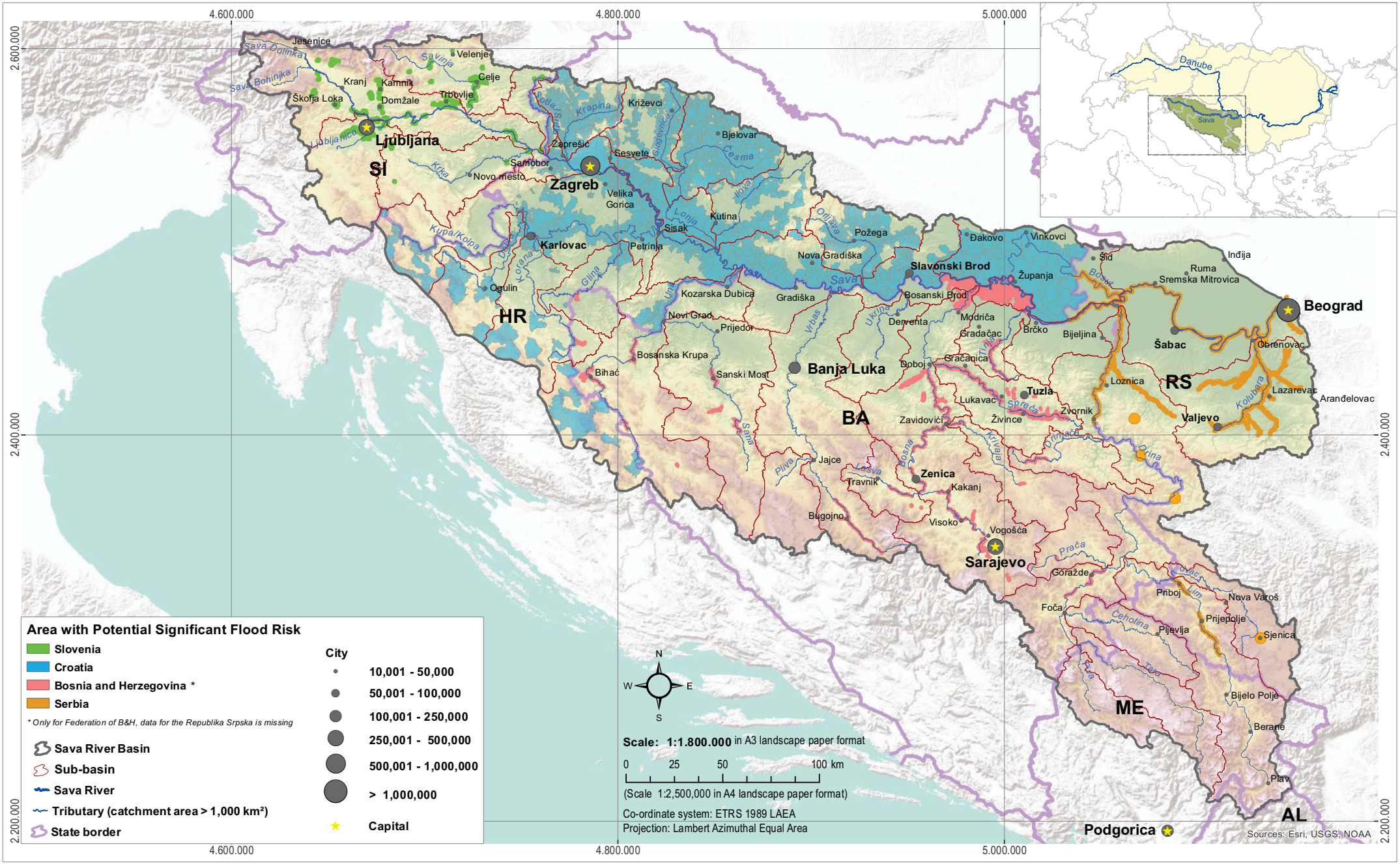
This product is based on national information provided by the Parties to the FASRB (SI, HR, BA, RS) and ME.
Corine Land Cover 2000 (EEA) was used as land cover layer.
Shuttle Radar Topography Mission (SRTM-3) from USGS Seamless Data Distribution System was used as topographic layer.
The boundaries and names shown and designations used on this map do not imply official endorsment or acceptance by the ISRBC.

PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

ISRBC Secretariat, 2014

Areas with potential significant flood risk in the Sava River Basin

MAP 4



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PRELIMINARY FLOOD RISK ASSESSMENT IN THE SAVA RIVER BASIN

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